Longitudinal Patterns of Performance: Te Poutama Tau

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Te Poutama Tau continues to focus on improving student performance in pāngarau (mathematics) through improving the professional capability of teachers. Te Poutama Tau is based on Te Mahere Tau (Ministry of Education, 2007a), the Number Framework of the Numeracy Development Projects, in which students progress through stages of learning. The considerable corpus of student achievement data collected during Te Poutama Tau provides information on longitudinal patterns of student performance. In general, Te Poutama Tau students' progress is more positive across the knowledge domains of Te Mahere Tau than across the strategy domains. The results show that a student's language proficiency does have some effect on performance, particularly on the use of strategies. The biggest influence on student performance, however, seems to be the teacher.

Background

Te Poutama Tau (the Māori-medium component of the Numeracy Development Projects [NDP]) developed from a 2002 pilot project (Christensen, 2003, 2004) and has evolved considerably over the last six years. The primary catalyst for the development of Te Poutama Tau was the opportunity to develop the teaching of mathematics (pāngarau) in the medium of Māori. Te Poutama Tau continues to focus on improving student performance in pāngarau through improving the professional capability of teachers. Te Mahere Tau (the Number Framework), which provides a clear description of the key concepts and progressions of learning for students, is central to Te Poutama Tau.

Te Poutama Tau data has provided a considerable corpus of data for analysis and investigation. Analyses of student achievement data gathered every year from 2002 has provided a valuable source of information for teachers, schools, and numeracy facilitators involved in Te Poutama Tau.

This paper is in two main parts. Part A reports on the results of the 2008 Te Poutama Tau programme, and Part B reports on longitudinal patterns of student performance. The research focused on the following questions:

- How do patterns of performance and progress compare across the years 2004–2008?
- What are the links between language and achievement?
- Is there a relationship between a student's initial point of entry and progress over time?
- What are the effect sizes between the variables of Te Mahere Tau?
- What are the key factors that affect change in student performance?

Part A: An Evaluation of Te Poutama Tau 2008

Method

Thirty-two schools participated in Te Poutama Tau in 2008, and 22 of these provided data for Part A of this paper. Each year, results for each Te Poutama Tau student, classroom, and school are entered on the national database (www.nzmaths.co.nz). The database shows the progress students have made on Te Mahere Tau between the initial and final diagnostic interviews (Te Uiui Aromatawai,

Ministry of Education, 2007b). In this part of the study, the 2008 results were compared with the longitudinal data dating back to 2004. The longitudinal results are discussed in Part B in terms of patterns of performance.

Participants

The following summaries of the data were restricted to those students with both initial and final test results. In 2006, 1153 students completed both the initial and final diagnostic interviews; in 2007, there was complete data for 1323 students; and in 2008, there was complete data for 766 students. Although a few year 9 and 10 students participated in 2006 (see Figure 1), a specific Te Poutama Tau programme was developed in 2007 and 2008 for students in wharekura (Māori-medium secondary), which accounts for the increase in numbers in these years.

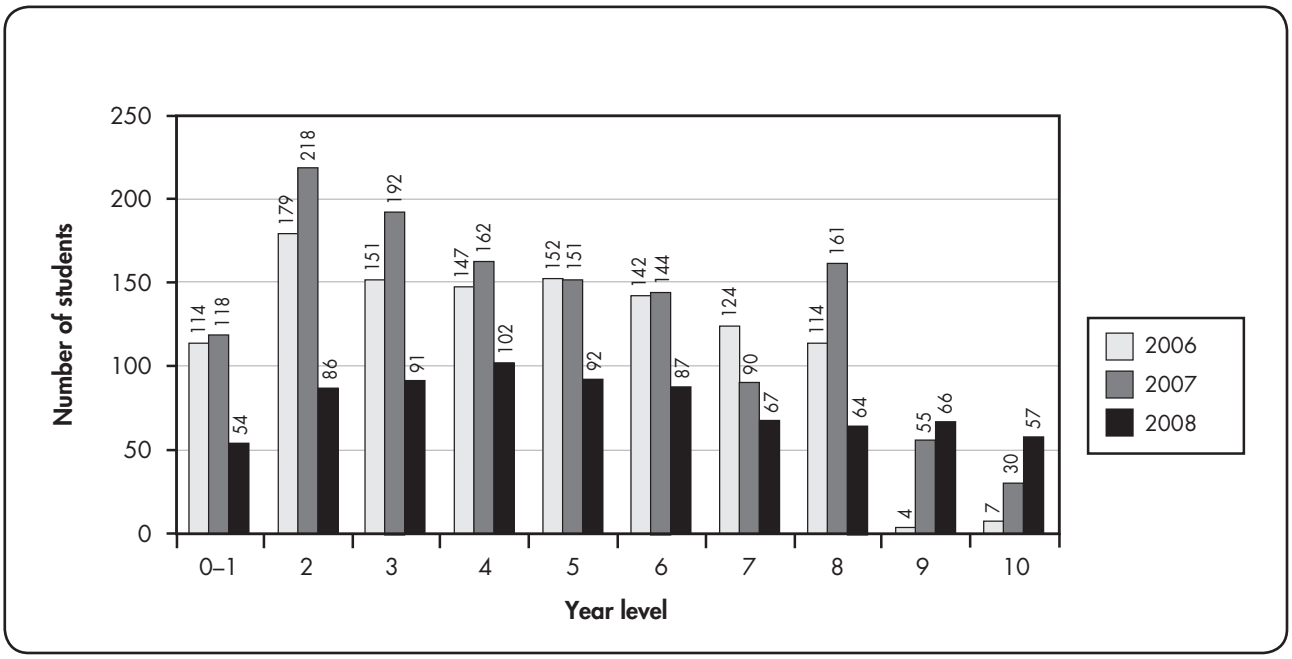

Figure 1. Distribution of Te Poutama Tau students across the year levels 2006–2008

Student Achievement and Year Level 2008

Strategy Domains

The graph in Figure 2 shows the variation in the mean gain for the strategy domains of Te Mahere Tau across the year levels. For example, students at years 0–1 made a mean stage gain of just under 1 for addition and subtraction, while at year 6, the mean gain was just over 0.6. A number of variables need to be considered when interpreting the results, including the increasing complexity of the stages (higher levels are more complex), the ceiling effect, and the number of years that students have been involved in Te Poutama Tau. It is expected that years 0–1 will make more progress in addition and subtraction than in multiplication and division or in proportions. Addition and subtraction is the only strategy domain included in Form A of the diagnostic interview (Uiui A), the interview most year 0–1 students will be assessed on. There is a noteworthy mean stage gain in 2008 in proportional thinking for year 2 (0.9) and year 3 (0.8) in comparison with 2007, where the mean stage gain for year 2 was 0.0 and for year 3 was 0.5 (Trinick & Stevenson, 2008).

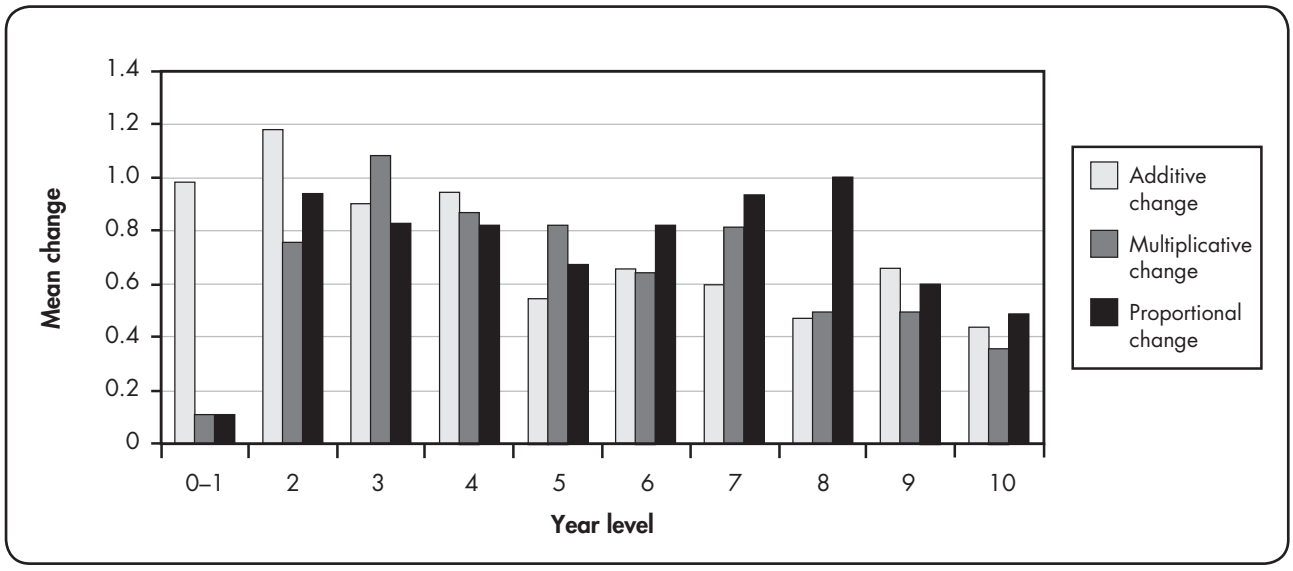

Figure 2. Mean stage gain by year level in 2008 for student achievement in strategy domains

Knowledge Domains

The knowledge domains tend to follow a similar pattern (Trinick & Stevenson, 2007, 2008). There is significant growth in the earlier years in FNWS (forward number word sequence) and BNWS (backward number word sequence), with a similar pattern of regression in later years. The regression can be partly explained by the ceiling effect, that is, a number of students in the older age groups may already be at the upper stages and will therefore not show any progress. It is also important to note that numeral identification (NID) (see Figure 3) as a separate data section is only part of Uiui A. Therefore students who proceed beyond tests A–E or to test U will not register mean stage progress in NID. These results do show that some year 6–8 students were tested on Uiui A.

With fractions, place value, and basic facts, there is growth initially, then a regression around years 5 and 6, and then some growth again. Students tend to start learning fractions later than place value and basic facts, and it is highly likely that the year 0–1 and year 2 students were tested on Uiui A. There is no fractions component in Uiui A, hence the lack of data for years 0–1.

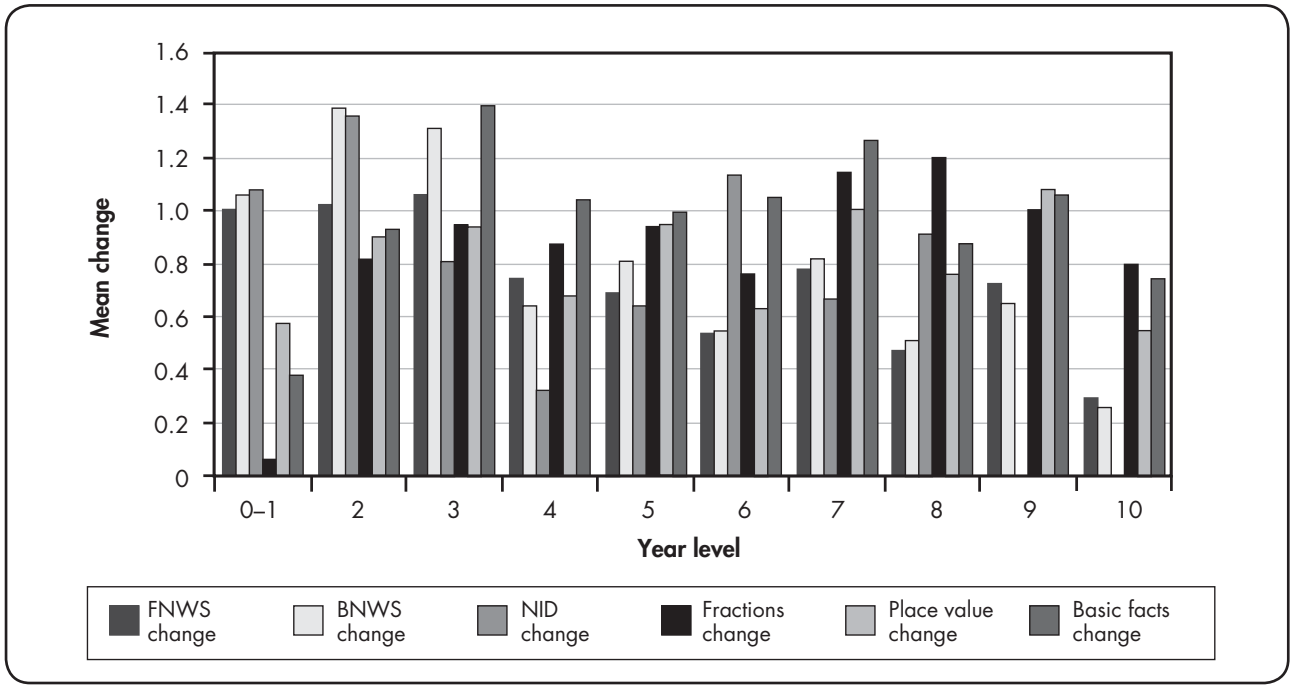

Figure 3. Mean stage gain by year level in 2008 for student achievement in knowledge domains

Language Spoken at Home

One of the key objectives of Te Poutama Tau has been to support the broader aims of Māori-medium schooling in the revitalisation of te reo Māori. The graph in Figure 4 shows that, for 2008, there were few students whose only home language was te reo Māori. This subjective judgment is made by the teacher who enters these results into the national database when they are entering student achievement data. For the majority of students, both English and Māori were spoken equally or English was spoken most of the time.

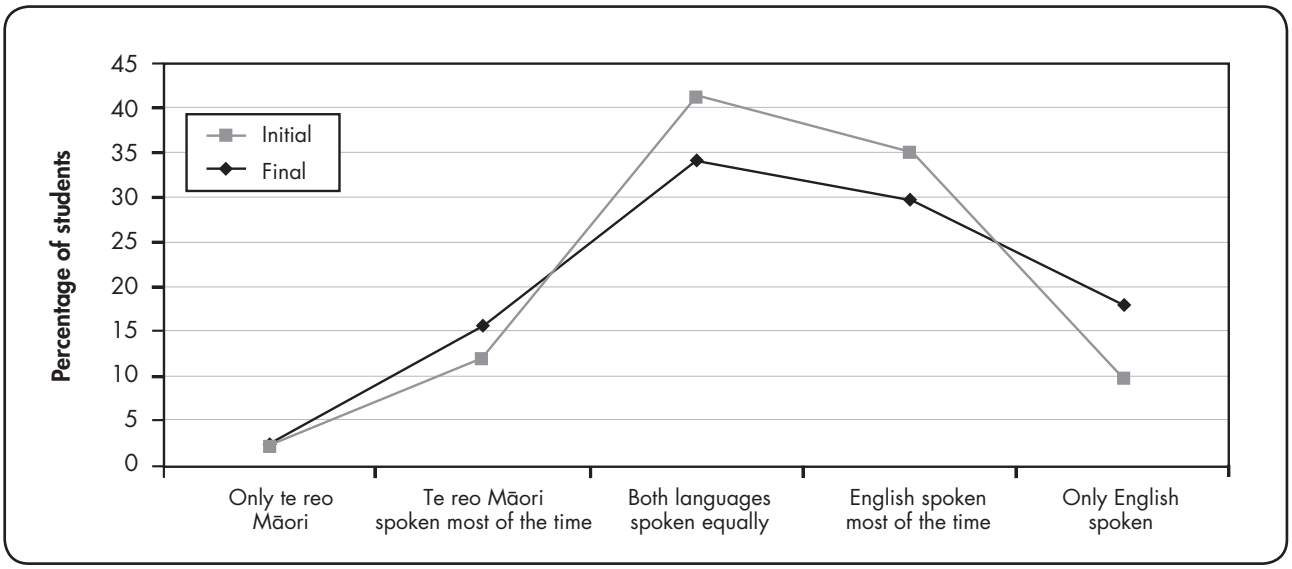

Figure 4. The language spoken at home by the 2008 Te Poutama Tau students

Language Proficiency of the Students

The majority of the students were classified as being either "he matatau" (proficient) and or "he āhua matatau" (reasonably proficient). These ratings rely on the teacher's knowledge of the student's language ability, drawn from a number of indicators, including their oral and written work. As with similar studies (Trinick & Stevenson, 2005, 2006), approximately 80% of the 2008 students are rated as either he matatau or he āhua matatau.

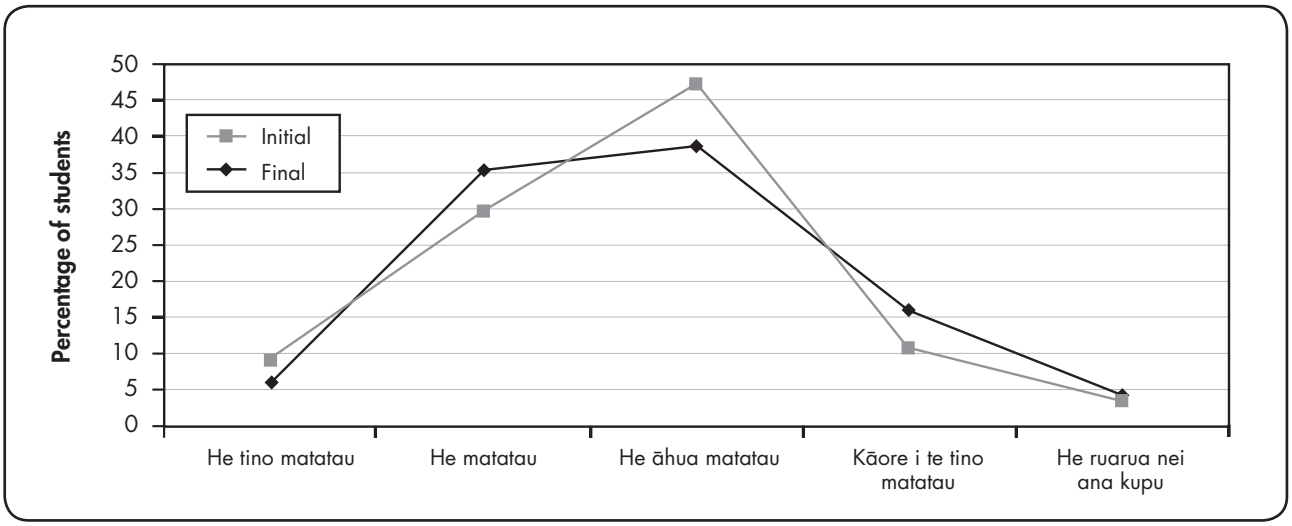

Figure 5. Te reo Māori proficiency of the 2008 students

Home Language by Mean Change

The graph in Figure 6 shows the mean stage gains across the strategy and knowledge domains of Te Mahere Tau in relation to the language(s) predominately spoken at home. The greatest mean stage gain seemed to be made by those students where Māori is spoken most of the time (Māori i te nuinga o te wā). However, the differences between each of the groups is not significant, although it is somewhat surprising that students whose home language was exclusively Māori (Māori anake) did not make similar or greater mean stage gains than those in the other groups. However, as noted previously, the rating is a subjective decision made by the teacher.

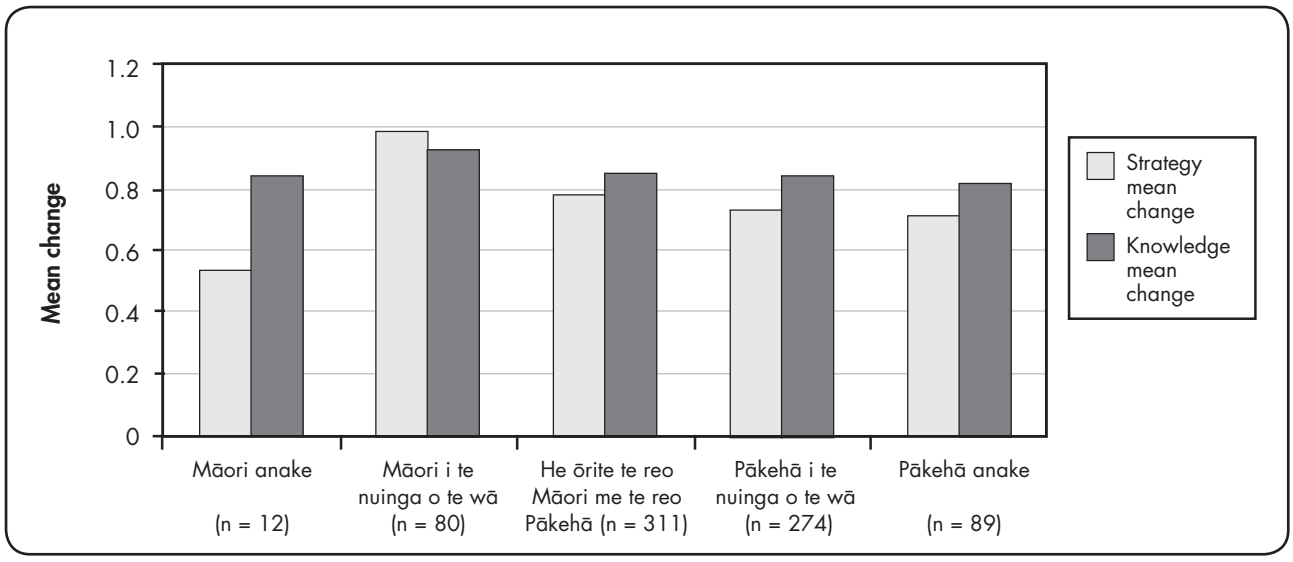

Figure 6. The 2008 mean stage gains across the strategy and knowledge domains in relation to home language

Teacher-rated Te Reo Māori Proficiency by Mean Change

The graph in Figure 7 shows the mean stage gain for the two major components of Te Mahere Tau in relation to students' levels of te reo Māori proficiency. As noted earlier in the discussion on Figure 6, this is a judgment made by the teacher based on the knowledge of their students.

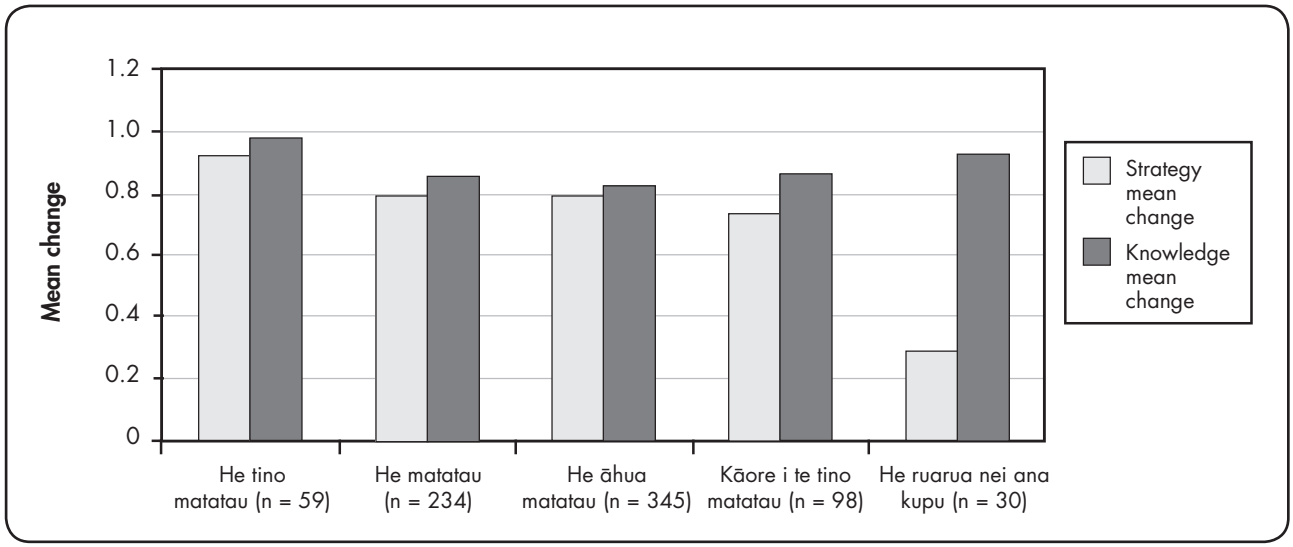

Figure 7. The 2008 mean stage gains across the strategy and knowledge domains in relation to students' language proficiency

This graph shows that the greatest mean stage gains across the two major domains (knowledge and strategies) were made by those students judged very proficient. The lowest mean gains in the

strategy domain were from the group identified as having very limited te reo Māori proficiency in the strategy domain. This is not surprising and is consistent with previous studies that have found that students do require a reasonable fluency to articulate their mental strategies (for example, Trinick & Stevenson, 2006).

In summary, the domains of fractions, decimals, percentages, and proportion remain learning challenges for students. These areas will need to remain a focus of the professional development programme that supports Te Poutama Tau. However, there has been positive progress in the area of proportional thinking for students in the early years. The patterns of progress across the various components of the knowledge domains are fairly consistent. There is significant growth in the early years, with a dip, particularly at year 5 (see figures 2 and 3). The language of the home appears to have some effect on student progress in Te Poutama Tau. However, the number of homes identified as speaking only Māori is small in number and the rating is done by the teacher. It is questionable whether the families themselves would provide a similar rating.

Part B: Longitudinal Patterns of Progress and Performance

As noted earlier, a considerable corpus of data has been collected that enables a range of general statements to be made about student achievement in Te Poutama Tau and the factors that do affect progress and performance. This section examines patterns of performance over the four years of the implementation of Te Poutama Tau and only includes the data of students who have participated in Te Poutama Tau for at least two to four years. Te Poutama Tau has predominately focused on the earlier years, hence most of the data comes from the earlier year groups.

Mean Stage Gains across Te Mahere Tau

The graph in Figure 8 shows the mean stage gains across the strategy and knowledge domains of Te Mahere Tau for the years 2005–2008. In general, students' progress is more positive across the knowledge domains of Te Mahere Tau than across the strategy domains. Each year's data has been used to provide a guide and focus for professional learning in subsequent years. For example, as a result of the 2006 and 2007 findings, there has been a continued focus on fractions and proportional thinking. The 2008 results for these two areas show positive stage gains because of this continued attention by facilitators and teachers to these two challenging areas of Te Mahere Tau.

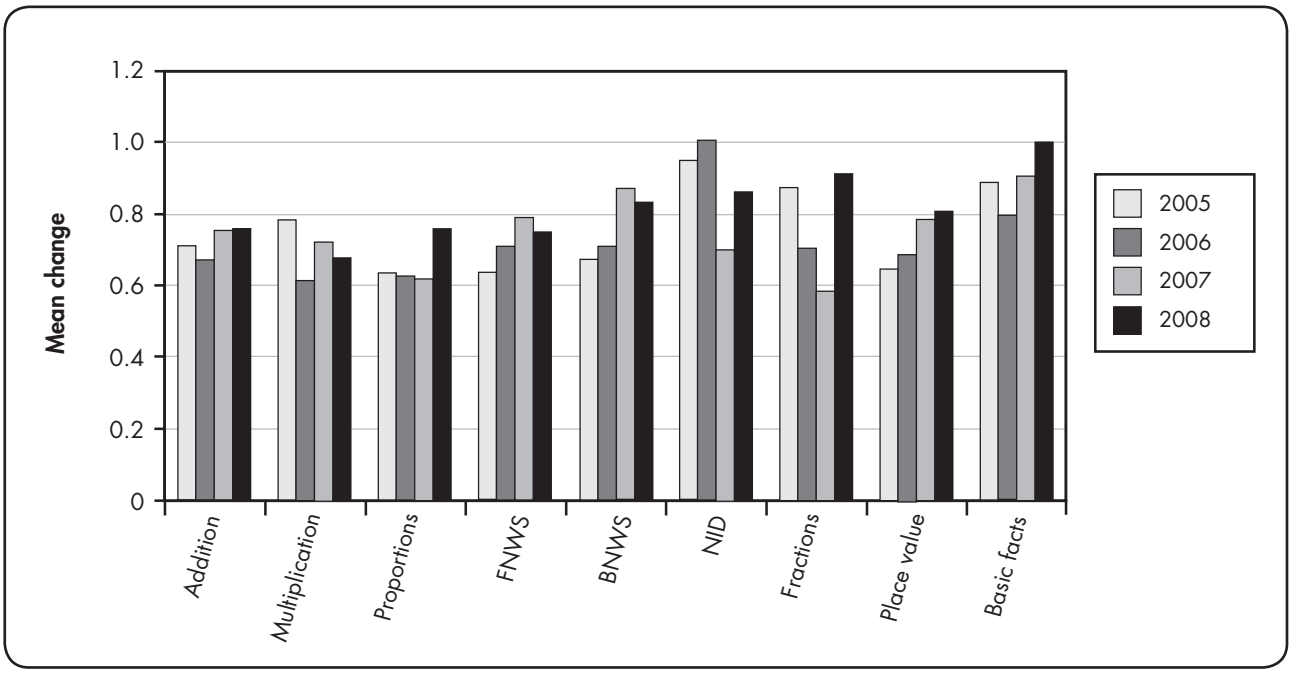

Figure 8. Mean stage gains across Te Mahere Tau

Average of Mean Stage Gains

Figure 9 shows how the average for the final results for all tests varies across the year levels for 2005–2008. This graph reflects the effect on progress through Te Mahere Tau of increasing stages of complexity and the ceiling effect. From year 2 to year 7, the trend is reasonably consistent. In most years, there has consistently been a dip at year 2, with a levelling off or rise in year 6. However, as noted earlier, it is important to interpret cautiously because the stages do not constitute an interval scale.

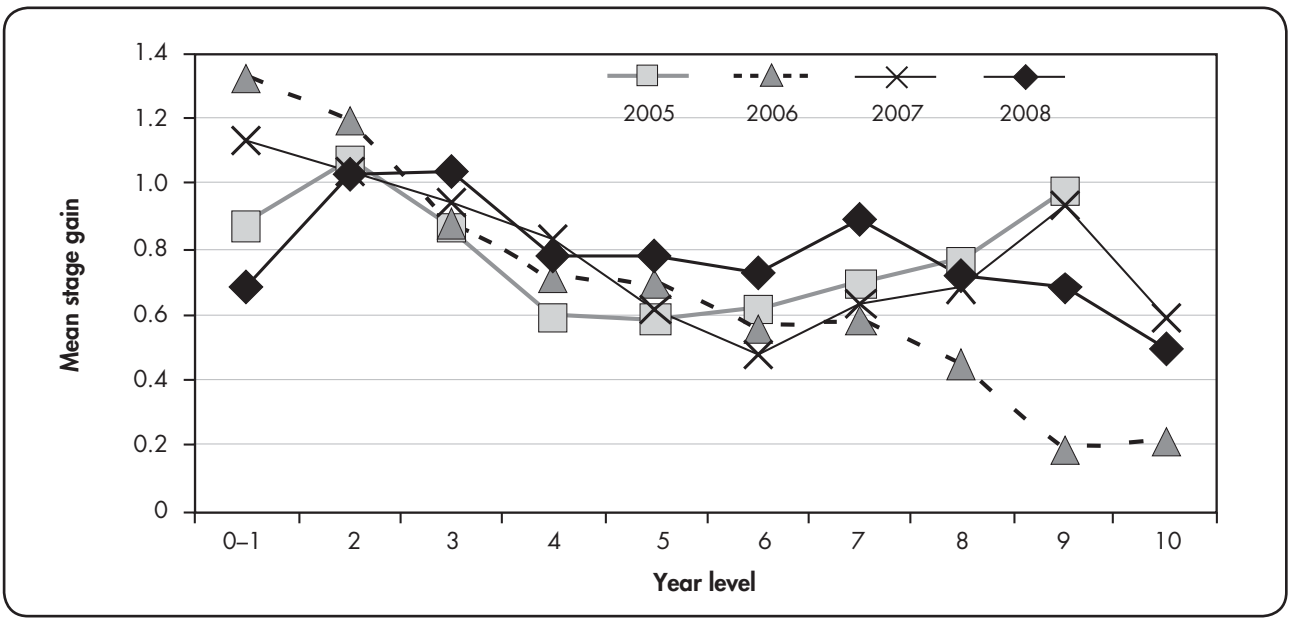

Figure 9. Comparison of students' average mean stage gain across the years 2005–2008

Stage of Entry (Strategy) and Progress over Time on Final Strategy Score

Figure 10 essentially shows that students who initially tested at a higher stage on the strategy tests at year 1 maintained that advantage (albeit a small one) for at least four years. There was only a small amount of data for students beyond year 4 who had been in Te Poutama Tau long enough to model the trends. Outcomes about performance after year 4 can be made when further data is collected or statistical modelling is completed.

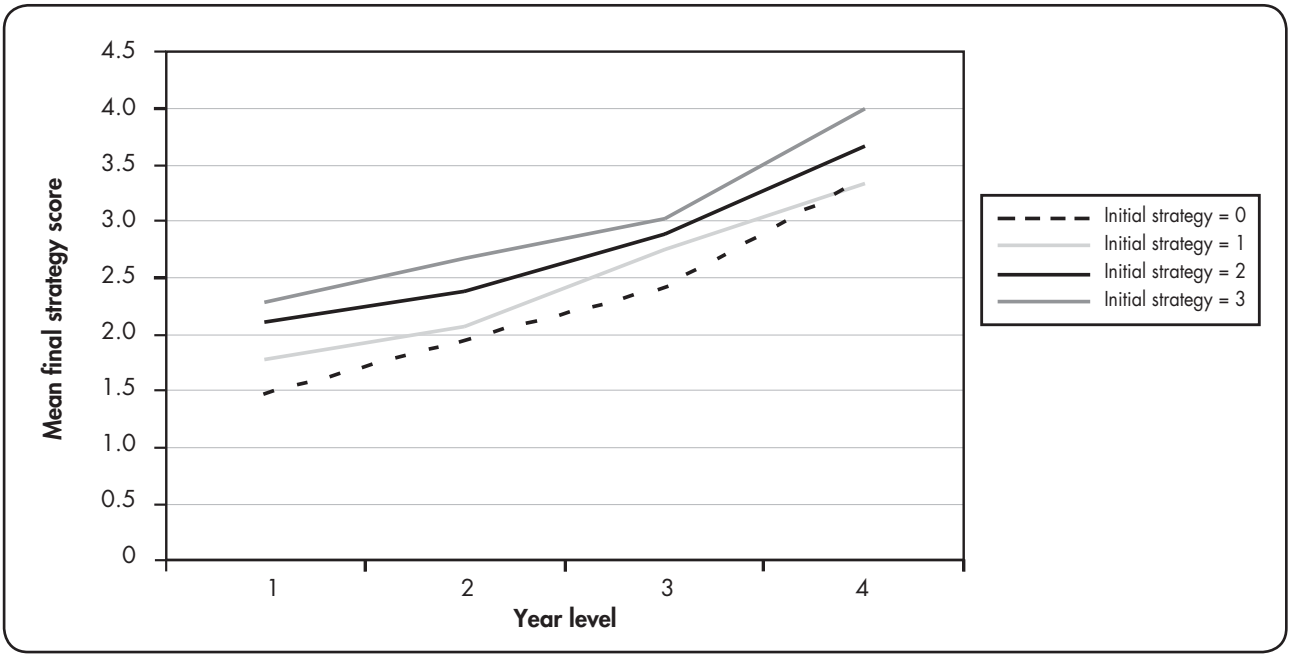

Figure 10. Strategy stage on entry and progress of time on final strategy score

Stage of Entry (Strategy) and Progress over Time on Final Knowledge Score

Figure 11 shows the relationship between the initial strategy stage at entry and students' mean final knowledge score. As with the graph in Figure 10 that shows performance on the tests of strategy, this graph seems to suggest that the higher the student's initial strategy score at year 1, the better their performance in the knowledge domains. This difference may be attributable to student ability as well as to any numerical learning prior to starting school.

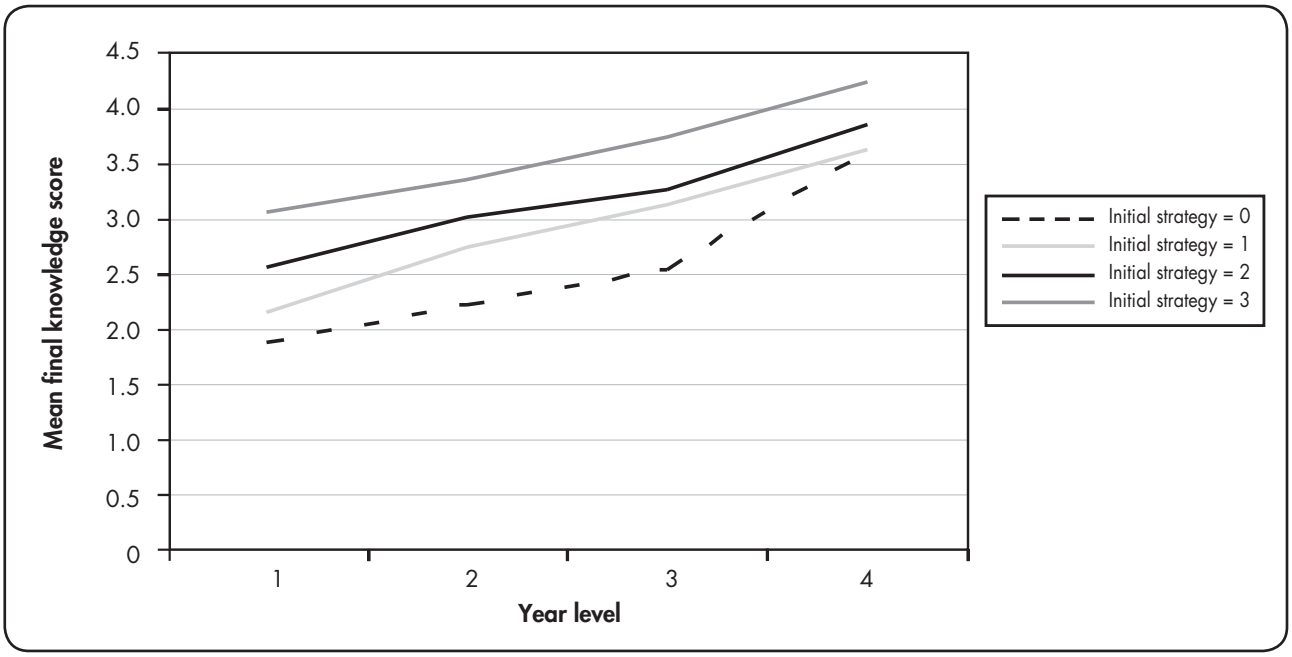

Figure 11. Strategy stage on entry and progress over time on final knowledge score

Home Language of Students

The following graph compares mean change for all domains by home language over the years 2004–2008. It is difficult to know why the mean change where Māori only is spoken at home is so variable across the years 2004–2008. This pattern could be attributed to the small numbers of students from homes that are rated as Māori-only speaking homes.

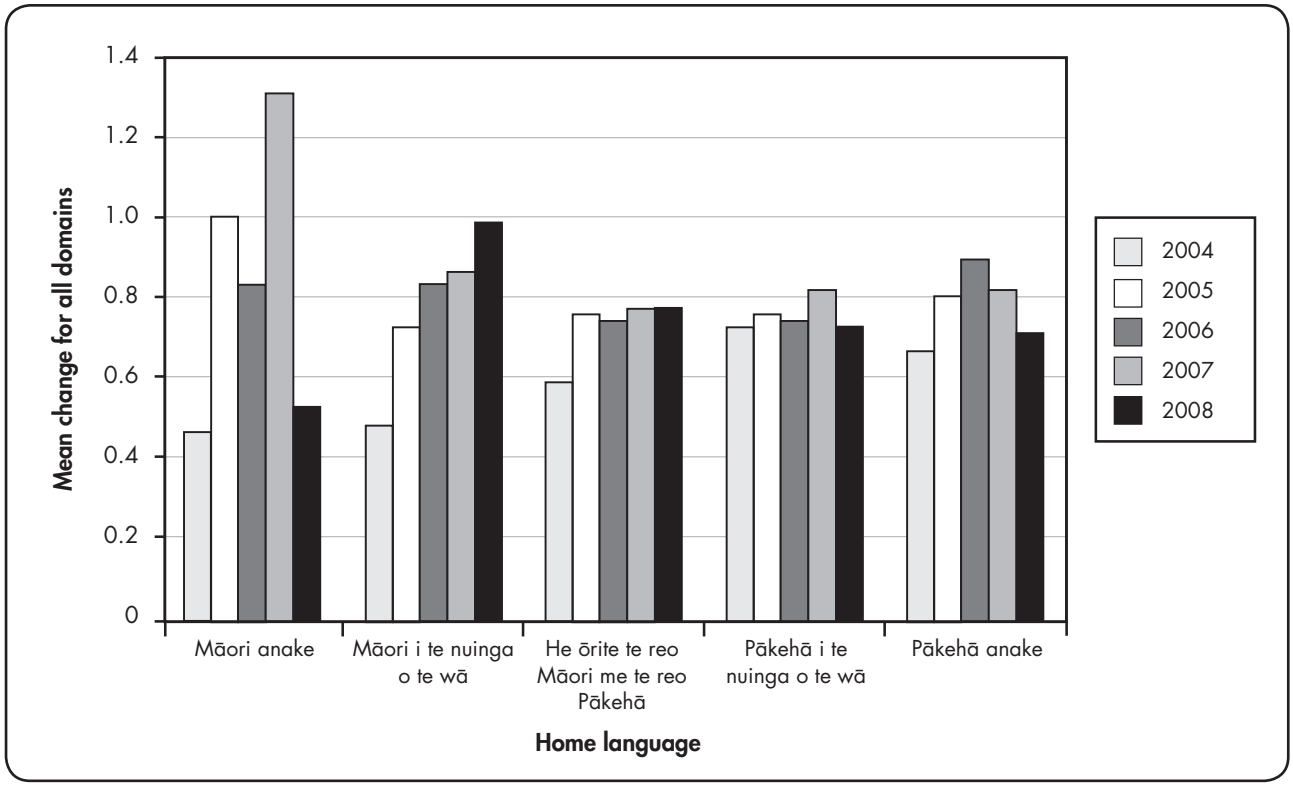

Figure 12. Mean change in relation to language spoken at home

Variables that Impact on Student Performance

One of the aims of Te Poutama Tau has been to identify the variables that impact on student performance and their effect sizes. The results were arrived at using Generalized Estimating Equations (GEE) analysis: students nested within classes, classes within schools, and repeated measurements for all data in the years 2003–2007. The GEE procedure allows the analysis of situations where the observations are correlated, such as repeated measurements and clustered sampling (for example, sampling participants within the same class). Such an analysis was necessary for the Te Poutama Tau data because one cannot assume independence of observations. Results for students will also depend on the class (teacher, class size, and so on) and the school (resourcing, location, bilingual/kura, and so on). The analysis was also conducted over time, with students linked by a common reference number[1]. The table in Appendix F (p. 185) summarises Beta coefficients and significance levels for each final score (on each test, for example, final addition score, final multiplication score) as a dependent variable, with the initial score on all the tests, year, gender, and language as dependents. The model also included all initial scores and language by year as a two-way interaction effect and a class nested within school.

Results

Overall, the analysis found that "class located within school" was statistically significant ($p < 0.001$) for all the dependent variables (the Beta coefficients were several orders larger than any other), with the significance of other terms varying depending on the dependent variable. This result is unsurprising, given that a number of researchers argue that the single largest influence on a student is the teacher (Hattie, 2003).

[1] This was done in Excel by comparing date of birth, school ID, year, and gender to find an appropriate match.

The Relationships between the Various Domains of Te Mahere Tau

The strength of the relationship between the various domains is measured by the correlation coefficient. The correlation coefficient is a measure of the degree of linear relationship between two variables. One cannot draw cause and effect conclusions based on correlation. Correlation refers to the strength of relationship between variables. The variables covered below have been identified as being significant ($p < 0.05$ – see Appendix F).

Addition/Subtraction

Only the class-within-school effect was statistically significant in the domains of addition and subtraction.

Multiplication/Division

A large number of variables were related to success in multiplication. Initial test results for addition, multiplication, and fractions were negatively correlated with multiplication final test results. Why this is so is not clear. Conversely, initial test results for proportions, FNWS, BNWS, NID, and place value were positively correlated with final test scores for multiplication. After accounting for interaction with year, the domains of proportions, FNWS, and place value showed small negative relationships with the final multiplication test result. Addition by year, multiplication by year, and fractions by year all showed small positive correlations.

Proportion

Initial addition scores were negatively related to the final proportions scores. Initial scores on multiplication, proportions, and fractions were positively correlated with final proportions scores.

FNWS and BNWS

Both final scores on FNWS and BNWS were positively correlated with initial scores on FNWS.

NID

Initial scores on proportions were negatively related with the final scores on the NID. The initial scores on the NID were positively related to the final scores.

Fractions

Initial scores on FNWS, fractions, and basic facts were positively related to final scores on fractions. A higher rating of the students' te reo Māori was positively related to a higher final score. There was also a positive relationship between gender and fractions, where boys tended to do slightly better in fractions than girls did.

Place Value

Initial scores for place value and basic facts were positively related to the place value final scores.

Basic Facts

Initial scores on basic facts were positively related to the students' final scores on the basic facts test.

Summary of Longitudinal Patterns of Progress

In general, Te Poutama Tau student progress is more positive across the knowledge domains of Te Mahere Tau than across the strategy domains. This may be partly attributed to language proficiency, where students do require a reasonable fluency to articulate their mental strategies. Fractions, decimals, percentages, and proportions remain a learning and teaching challenge for students and teachers. Te Poutama Tau has been valuable in providing opportunities for facilitators and teachers alike to develop the mathematics register to facilitate student learning in domains such as fractions. In teacher professional learning programmes for Māori-medium teachers, it is important to introduce an intellectualised variety of te reo Māori at a high level in order to develop the professional competency of the teachers who will in turn implement an intellectualised variety of te reo Māori in primary and secondary schools. This enhances the development of the school-based Māori-medium mathematics register.

The patterns of progress are very similar across years 2005–2008 for year 2–8 students (see Figure 9), with a consistent dip around the 5–6 year level. The patterns of progress reflect the nature of Te Mahere Tau, that is, the increasing complexity of the stages and the struggle that many students seem to have in transitioning to part–whole thinking. It would seem that where there has been a Te Poutama Tau facilitator and teacher focus on particular areas of Te Mahere Tau, there has been a corresponding improvement in student performance the following year. This suggests that student progress is affected by a number of variables, including teacher competence, quality of time spent learning, and the quality and availability of support resources.

The longitudinal data (see figures 10 and 11) shows that students who initially tested at a higher stage on Te Mahere Tau maintained that advantage to at least year 4. Outcomes about performance after year 4 can be made when further data is collected.

Nationally and internationally, little is known of the impact of a student's language proficiency on their learning of mathematics. The issues of language proficiency and the learning of mathematics are complex areas in their own right. However, the analyses of the data from Te Poutama Tau suggests that the language proficiency of a student does have an effect on their ability to articulate their mental strategies. This is not necessarily a problem if the test is written, but it may impinge on the student's ability to communicate. Many researchers and national policy documents (Pimm, 1987; Ministry of Education, 2008) support the idea of encouraging students to communicate mathematically. Being able to communicate requires students to extract meaning from mathematics statements and to convey that meaning in spoken or written discourse.

As noted, one of the aims of Te Poutama Tau has been to identify the variables that impact on student performance and their effect sizes. Overall, the analysis of the data found that class located within school was statistically significant. This result is unsurprising, given that a number of researchers argue that the single largest influence on a student is the teacher (Hattie, 2003). However, this Te Poutama Tau study does not consider a number of variables that impact on student learning, including the social, cultural, and economic impacts. Mathematics contains many interrelated domains and concepts. This study suggests that students' knowledge of multiplication affects a number of other domains, including fractions, decimals, percentages, and proportions. This has implications for the learning of these challenging areas for students.

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